

Clariant GmbH

1999DE321/02

## NOVEL AMINOPHOSPHONIUM COMPOUNDS

## 5 BACKGROUND OF THE INVENTION

The present invention relates to novel aminophosphonium compounds, to substance mixtures containing them, and to the preparation and use thereof.

10 Aminophosphonium compounds are used, as is evident from WO 98/32532 and WO 98/22413, as catalysts for preparing fluorine-containing compounds by a halogen/fluorine exchange reaction (halex reaction). Although the tetrakis-(diethylamino)phosphonium bromide used in WO 98/32532 and WO 98/22413 gives good results, it has a very high dermal toxicity which stands in the way of industrial use, however.

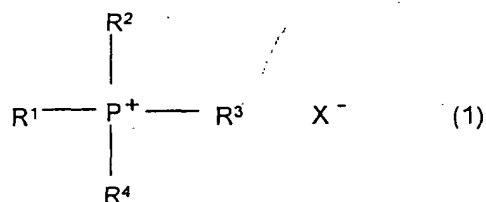
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## SUMMARY OF THE INVENTION

The object is to provide novel compounds which are suitable as catalyst or component of catalyst systems for phase-transfer reactions, in particular for halogen-fluorine exchange reactions, have a lower dermal toxicity and achieve or even  
20 exceed the results obtainable on use of tetrakis(diethylamino)phosphonium bromide.

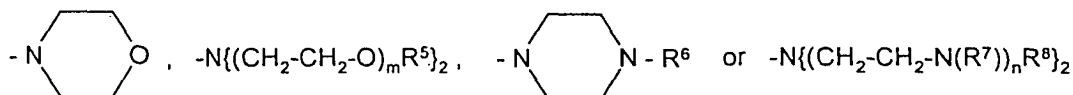
## DESCRIPTION OF THE PREFERRED EMBODIMENTS

This object is achieved by compounds of the formula

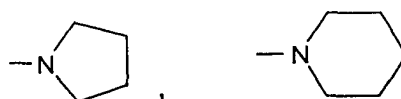


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in which one, two or three of the radicals  $\text{R}^1$ ,  $\text{R}^2$ ,  $\text{R}^3$  and  $\text{R}^4$  are



where m and n are an integer from 1 to 10,  $\text{R}^5$ ,  $\text{R}^6$ ,  $\text{R}^7$  and  $\text{R}^8$  are, independently of one another, identical or different and are a straight-chain or branched alkyl radical having 1 to 10 carbon atoms, and the remaining radical(s)  $\text{R}^1$  to  $\text{R}^4$  are



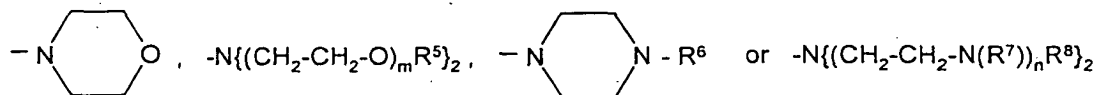
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or  $-\text{NR}^9\text{R}^{10}$ , where  $\text{R}^9$  and  $\text{R}^{10}$  are identical or different and are a straight-chain or branched alkyl radical having 1 to 10 carbon atoms,

and  $\text{X}^-$  is an inorganic or organic anion or an equivalent of a multiply charged inorganic or organic anion.

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Compounds of interest are those of the formula (1) in which one or two of the radicals  $\text{R}^1$ ,  $\text{R}^2$ ,  $\text{R}^3$  and  $\text{R}^4$  are



and the remaining radicals  $\text{R}^1$  to  $\text{R}^4$  are



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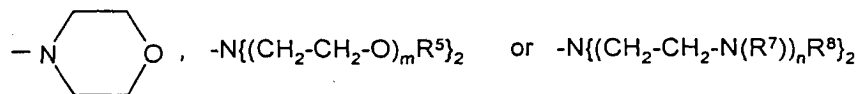
or  $-\text{NR}^9\text{R}^{10}$ .

Importance further attaches to compounds of the formula (1) in which m and n are an integer from 1 to 6, and  $\text{R}^5$ ,  $\text{R}^6$ ,  $\text{R}^7$ ,  $\text{R}^8$ ,  $\text{R}^9$  and  $\text{R}^{10}$  are identical or different and are a

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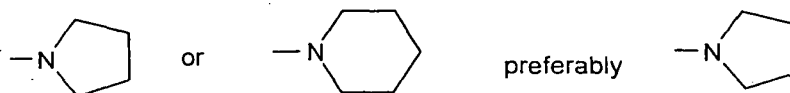
straight-chain or branched alkyl radical having 1 to 4 carbon atoms.

The aforementioned radicals  $\text{R}^1$ ,  $\text{R}^2$ ,  $\text{R}^3$  and  $\text{R}^4$  are, in particular,



preferably  $-N\{(CH_2-CH_2-O)_mR^5\}_2$  or  $-N\{(CH_2-CH_2-N(R^7))_nR^8\}_2$ , particularly preferably  $-N\{(CH_2-CH_2-O)_mR^5\}_2$ .

The aforementioned remaining radical(s)  $R^1$  to  $R^4$  are, in particular,



In the compounds of the formula (1),  $X^-$  is  $F^-$ ,  $Cl^-$ ,  $Br^-$ ,  $I^-$ ,  $ClO_4^-$ ,  $BF_4^-$ ,  $PF_6^-$ ,  $NO_3^-$ ,  $HSO_4^-$ ,  $\frac{1}{2} SO_4^{2-}$ ,  $H_2PO_4^-$ ,  $\frac{1}{2} HPO_4^{2-}$ ,  $\frac{1}{3} PO_4^{3-}$ ,  $R'-COO^-$ , where  $R'$  is an alkyl radical having 1 to 9 carbon atoms, a phenyl radical, benzyl radical or naphthyl radical,  $R''-SO_3^-$ , where  $R''$  is an alkyl radical having 1 to 18 carbon atoms, a phenyl radical, tolyl radical or naphthyl radical,  $HCO_3^-$ ,  $\frac{1}{2} CO_3^{2-}$  or  $\frac{1}{2} C_6H_4(COO^-)_2$ .

$X^-$  is, in particular,  $F^-$ ,  $Cl^-$ ,  $Br^-$ ,  $I^-$ ,  $BF_4^-$ ,  $PF_6^-$  or  $\frac{1}{2} SO_4^{2-}$ , preferably  $F^-$ ,  $Cl^-$ , or  $Br^-$ , particularly preferably  $Cl^-$ .

- 15 The following aminophosphonium compounds (aminophosphonium salts) may be mentioned as examples without claiming completeness.

Bis(2-methoxyethyl)amino-tris(pyrrolidino)phosphonium chloride

Di(bis(2-methoxyethyl)amino)-bis(pyrrolidino)phosphonium chloride

- 20 Tri(bis(2-methoxyethyl)amino)-(pyrrolidino)phosphonium chloride

Bis(methyl-diethoxyethylene)amino-tris(pyrrolidino)phosphonium chloride

Di(bis(methyl-diethoxyethylene)amino)-bis(pyrrolidino)phosphonium chloride

Tri(bis(methyl-diethoxyethylene)amino)-(pyrrolidino)phosphonium chloride

Bis(methyl-tetraethoxyethylene)amino-tris(pyrrolidino)phosphonium chloride

- 25 Di(bis(methyl-tetraethoxyethylene)amino)-bis(pyrrolidino)phosphonium chloride

Tri(bis(methyl-tetraethoxyethylene)amino)-(pyrrolidino)phosphonium chloride

Morpholino-tris(pyrrolidino)phosphonium chloride

Dimorpholino-bis(pyrrolidino)phosphonium chloride

Trimorpholino-(pyrrolidino)phosphonium chloride

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Bis(2-methoxyethyl)amino-tris(piperidino)phosphonium chloride

- Di(bis(2-methoxyethyl)amino)-bis(piperidino)phosphonium chloride  
 Tri(bis(2-methoxyethyl)amino)-(piperidino)phosphonium chloride  
 Bis(methyl-diethoxyethylene)amino-tris(piperidino)phosphonium chloride  
 Di(bis(methyl-diethoxyethylene)amino)-bis(piperidino)phosphonium chloride  
 5 Tri(bis(methyl-diethoxyethylene)amino)-(piperidino)phosphonium chloride  
 Bis(methyl-tetraethoxyethylene)amino-tris(piperidino)phosphonium chloride  
 Di(bis(methyl-tetraethoxyethylene)amino)-bis(piperidino)phosphonium chloride  
 Tri(bis(methyl-tetraethoxyethylene)amino)-(piperidino)phosphonium chloride  
 Morpholino-tris(piperidino)phosphonium chloride  
 10 Dimorpholino-bis(piperidino)phosphonium chloride
- Bis(2-methoxyethyl)amino-tris(diethylamino)phosphonium chloride  
 Di(bis(2-methoxyethyl)amino)-bis(diethylamino)phosphonium chloride  
 Tri(bis(2-methoxyethyl)amino)-(diethylamino)phosphonium chloride  
 15 Bis(methyl-tetraethoxyethylene)amino-tris(diethylamino)phosphonium chloride  
 Di(bis(methyl-tetraethoxyethylene)amino)-bis(diethylamino)phosphonium chloride  
 Tri(bis(methyl-tetraethoxyethylene)amino)-(diethylamino)phosphonium chloride  
 Morpholino-tris(diethylamino)phosphonium chloride  
 Dimorpholino-bis(diethylamino)phosphonium chloride  
 20 Trimorpholino-(diethylamino)phosphonium chloride
- Bis(2-methoxyethyl)amino-tris(dimethylamino)phosphonium chloride  
 Di(bis(2-methoxyethyl)amino)-bis(dimethylamino)phosphonium chloride  
 Tri(bis(2-methoxyethyl)amino)-(dimethylamino)phosphonium chloride  
 25 Bis(methyl-bisethoxyethylene)amino-tris(dimethylamino)phosphonium chloride  
 Di(bis(methyl-bisethoxyethylene)amino)-bis(dimethylamino)phosphonium chloride  
 Tri(bis(methyl-bisethoxyethylene)amino)-(dimethylamino)phosphonium chloride  
 Bis(methyl-tetraethoxyethylene)amino-tris(dimethylamino)phosphonium chloride  
 Di(bis(methyl-tetraethoxyethylene)amino)-bis(dimethylamino)phosphonium chloride  
 30 Tri(bis(methyl-tetraethoxyethylene)amino)-(dimethylamino)phosphonium chloride  
 Tris(dimethylamino)-morpholino-phosphonium chloride  
 Bis(dimethylamino)-dimorpholino-phosphonium chloride  
 Dimethylamino-trimorpholino-phosphonium chloride

Bis(2-methoxyethyl)amino-tris(butyl-ethylamino)phosphonium chloride

Di(bis(2-methoxyethyl)amino)-bis(butyl-ethylamino)phosphonium chloride

Tri(bis(2-methoxyethyl)amino)-(butyl-ethylamino)phosphonium chloride

5 Bis(methyl-tetraethoxyethylene)amino-tris(butyl-ethylamino)phosphonium chloride

Di(bis(methyl-tetraethoxyethylene)amino)-bis(butyl-ethylamino)phosphonium  
chloride

Tri(bis(methyl-tetraethoxyethylene)amino)-(butyl-ethylamino)phosphonium chloride

Tris(butyl-ethylamino)-morpholino-phosphonium chloride

10 Bis(butyl-ethylamino)-dimorpholino-phosphonium chloride

(Butyl-ethylamino)-trimorpholino-phosphonium chloride

N-Methylpiperazino-tris(pyrrolidino)phosphonium chloride

Bis(N-methylpiperazino)-bis(pyrrolidino)phosphonium chloride

Tris(N-methylpiperazino)-(pyrrolidino)phosphonium chloride

15 N-Methylpiperazino-tris(diethylamino)phosphonium chloride

Bis(N-methylpiperazino)-bis(diethylamino)phosphonium chloride

Tris(N-methylpiperazino)-(diethylamino)phosphonium chloride

N-Methylpiperazino-tris(dimethylamino)phosphonium chloride

Bis(N-methylpiperazino)-bis(dimethylamino)phosphonium chloride

20 Tris(N-methylpiperazino)-(dimethylamino)phosphonium chloride

N-Methylpiperazino-tris(butyl-ethylamino)phosphonium chloride

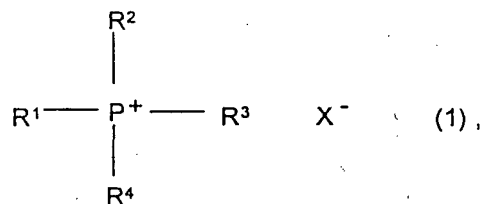
Bis(N-methylpiperazino)-bis(butyl-ethylamino)phosphonium chloride

Tris(N-methylpiperazino)-(butyl-ethylamino)phosphonium chloride

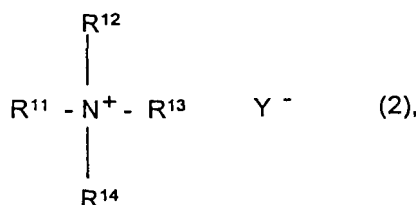
25 In place of the listed aminophosphonium chlorides it is also possible to employ, for example, the corresponding bromides, iodides, fluorides, sulfates, hydrogen sulfates, acetates or phthalates.

The present invention also relates to mixtures of substances comprising at least one

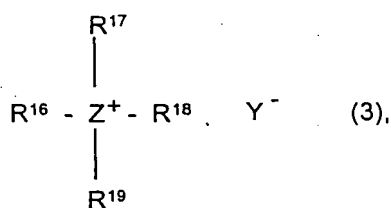
30 compound of the formula



in which  $\text{R}^1$ ,  $\text{R}^2$ ,  $\text{R}^3$ ,  $\text{R}^4$  and  $\text{X}^-$  have the above meaning, and at least one compound selected from the group of quaternary ammonium compounds of the formula



quaternary ammonium salts or phosphonium salts of the formula



polyethers of the formula  $\text{R}^{20}-(\text{O}-\text{C}_x\text{H}_{2x})_s-\text{OR}^{21}$  (4) and crown ethers,

in which in formula (2)  $\text{R}^{11}$ ,  $\text{R}^{12}$  and  $\text{R}^{13}$  are identical or different and are a linear or branched radical of the formula  $-(\text{C}_p\text{H}_{2p}\text{O})_r\text{R}^{15}$  in which  $\text{R}^{15}$  is hydrogen or a linear or branched alkyl radical having 1 to 16 carbon atoms,  $p$  is an integer from 1 to 10 and  $r$  is an integer from 1 to 15;

or a linear or branched alkyl radical having 1 to 30 carbon atoms;

or an unsubstituted phenyl or naphthyl radical, or a substituted phenyl or naphthyl radical, where the substituents have the meaning of halogen,  $\text{C}_1$ - $\text{C}_4$ -alkyl,  $\text{C}_1$ - $\text{C}_4$ -

alkoxy, nitro or cyano;

$\text{R}^{14}$  is a linear or branched radical of the formula  $-(\text{C}_p\text{H}_{2p}\text{O})_r\text{R}^{15}$  and

$\text{Y}^-$  is an inorganic anion;

and in formula (3)

$R^{16}$ ,  $R^{17}$ ,  $R^{18}$  and  $R^{19}$  are identical or different and are a linear or branched alkyl radical having 1 to 22 carbon atoms; or an unsubstituted or substituted aryl radical or a  $C_1$ - $C_4$ -alkylaryl radical, where aryl has the meaning of phenyl or naphthyl, and said substituents are halogen,

$C_1$ - $C_4$ -alkyl,  $C_1$ - $C_4$ -alkoxy, nitro or cyano; Z has the meaning of N or P, and  $Y^-$  is an inorganic anion;

and in formula (4)

$R^{20}$  and  $R^{21}$  are identical or different and are a linear or branched alkyl radical having 1 to 16 carbon atoms;

x is an integer from 2 to 6 and

s is an integer from 1 to 60;

or one of the radicals  $R^{20}$  and  $R^{21}$  is hydrogen and the other one of the radicals is a linear or branched alkyl radical having 1 to 16 carbon atoms,

x is an integer from 2 to 6 and s is an integer from 2 to 50, or the radicals  $R^{20}$  and  $R^{21}$  are hydrogen, x is an integer from 2 to 6 and s is an integer from 3 to 5.

The present invention relates in particular to mixtures of substances which comprise at least one compound of the formula (1) and at least one compound selected from the group of quaternary ammonium compounds of the formula (2), quaternary ammonium salts and phosphonium salts of the formula (3), polyethers of the formula (4) and crown ethers, in which in formula (2)  $R^{11}$ ,  $R^{12}$  and  $R^{13}$  are identical or different and are a linear or branched radical of the formula  $-(C_pH_{2p}O)_rR^{15}$  in which  $R^{15}$  is hydrogen or a linear or branched alkyl radical having 1 to 8 carbon atoms, p is an integer from 1 to 5 and r is an integer from 2 to 10; or a linear or branched alkyl radical having 1 to 18 carbon atoms; or an unsubstituted phenyl or naphthyl radical;  $R^{14}$  is a linear or branched radical of the formula  $-(C_pH_{2p}O)_rR^{15}$ , in which  $R^{15}$  is hydrogen or a linear or branched alkyl radical having 1 to 8 carbon atoms, p is an integer from 1 to 5 and r is an integer from 2 to 10; and  $X^-$  is fluoride, chloride, bromide,  $SO_4^{2-}/2$  or hydrogen sulfate.

Mixtures of substances of particular interest are those comprising at least one compound of the formula (1) and at least one compound from the group of quaternary ammonium compounds of the formula (2).

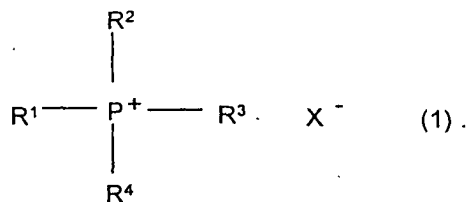
- 5    Mention should also be made of mixtures of substances of the above type comprising at least one ammonium salt or phosphonium salt of the formula (3), in which in formula (3)  $R^{16}$ ,  $R^{17}$ ,  $R^{18}$  and  $R^{19}$  are identical or different and are a linear or branched alkyl radical having 1 to 16 carbon atoms; or an unsubstituted or substituted aryl radical or a  $C_1$ - $C_4$ -alkylaryl radical, where aryl has the meaning of  
10    phenyl or naphthyl, and said substituents are halogen,  $C_1$ - $C_4$ -alkyl,  $C_1$ - $C_4$ -alkoxy, nitro or cyano.

- Mixtures of substances of the above type comprising at least one polyether of the formula (4) or crown ether, in which in formula (4)  $R^{20}$  and  $R^{21}$  are identical or  
15    different and are hydrogen or a linear or branched alkyl radical having 1 to 8 carbon atoms, x is an integer from 2 to 3 and s is an integer from 4 to 50, are likewise of interest.

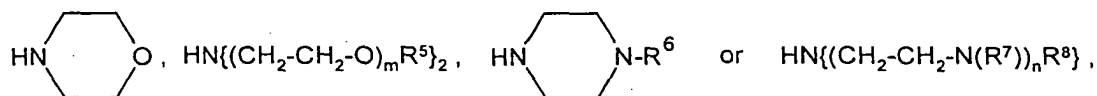
- The mixtures of substances normally comprise from 5 to 95% by weight, in particular  
20    20 to 80% by weight, preferably 25 to 75% by weight, of at least one compound of the formula (1). The residual 95 to 5% by weight, in particular 80 to 20% by weight, preferably 75 to 25% by weight, of the mixtures of substances account for the remainder, namely at least one compound selected from the group of quaternary ammonium compounds of the formula (2) of quaternary ammonium or phosphonium  
25    salts of the formula (3), polyethers of the formula (4) and crown ethers, in particular at least one compound from the group of quaternary ammonium compounds of the formula (2).

- The present invention further relates to a process for preparing compounds of the  
30    formula



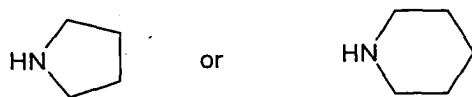


It comprises reacting a phosphorus pentahalide in the presence of an inert solvent at  
 -70 to 140°C, in particular -30 to 120°C, preferably -15 to 60°C, with from 1 to 6 mol,  
 5 in particular 1 to 2.5 mol, of



per halogen equivalent to be exchanged, and subsequently reacting the reaction  
 product with from 1 to 10 mol, in particular 1 to 3 mol, of

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or  $\text{HNR}^9\text{R}^{10}$  per halogen equivalent still to be exchanged. This reaction of the  
 reaction product takes place at -15 to 140°C, in particular 0 to 130°C, preferably 20  
 15 to 130°C.

The phosphorus pentahalide employed is  $\text{PCl}_5$  or  $\text{PBr}_5$ , in particular  $\text{PCl}_5$ .

The inert solvent employed is an aliphatic, cycloaliphatic or aromatic hydrocarbon or  
 20 a mono- or polychlorinated aliphatic, cycloaliphatic or aromatic hydrocarbon.

Very suitable inert solvents are, for example, hexane, cyclohexane,  
 methylcyclohexane, toluene, ethylbenzene, mesitylene, o-xylene, m-xylene,  
 p-xylene, technical mixtures of isomeric xylenes, methylene chloride,  
 25 tetrachloroethane, chlorobenzene, dichlorobenzene or chlorotoluene. It is also  
 possible to use mixtures of solvents.

The phosphorus pentahalide is suspended or dissolved in the inert solvent and the reaction is carried out with the addition of the aforementioned nitrogen-containing compounds.

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This results in compounds of the formula (1) in which  $X^-$  is a halide. If required, the halide can be exchanged for another one of the aforementioned anions by metathesis.

- 10 The invention further relates to the use of the compounds of the formula (1) as catalyst and cocatalyst for phase-transfer reactions, nucleophilic substitutions and halogen-fluorine exchange reactions.

- 15 The invention further relates to the use of the mixtures of substances comprising at least one compound of the formula (1) and at least one compound selected from the group of quaternary ammonium compounds of the formula (2), quaternary ammonium salts or phosphonium salts of the formula (3), polyethers of the formula (4) and crown ethers as catalyst for phase-transfer reactions, nucleophilic substitutions and halogen-fluorine exchange reactions.

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## EXAMPLES

The following examples describe the present invention further without restricting it.

### Experimental section

- 25 Preparation of the aminophosphonium compounds (aminophosphonium salts)  
Example 1: Bis(2-methoxyethyl)amino-tris(pyrrolidino)phosphonium chloride

- 104.12 g (0.5 mol) of phosphorus pentachloride are introduced into 400 g of chlorobenzene and cooled to  $-20$  to  $-10^\circ\text{C}$ . At this temperature, 66.89 g (0.5 mol) of  
30 bis-(2-methoxyethyl)amine are added dropwise in such a way that the internal temperature does not exceed  $0^\circ\text{C}$ . After the addition, the mixture is allowed to warm slowly to  $30^\circ\text{C}$  and is then heated at  $90$ - $100^\circ\text{C}$  for one hour.

It is then cooled again to 10°C, and 214.5 g (3.0 mol) of pyrrolidine are added dropwise in such a way that the internal temperature does not exceed 15°C. After the addition, the mixture is heated to reflux for two hours.

After cooling to 0°C, 779.94 g (3.9 mol) of 20% strength sodium hydroxide solution are cautiously used to make alkaline. The aqueous phase is separated off and discarded. Excess amine is then distilled out of the organic phase. After the end of the distillation, HCl is used to acidify to pH=6-7 and, after filtration, the chlorobenzene is stripped off in a rotary evaporator.

Elemental analysis: C=55.2%, H=8.9%, N=12.9%, P=7.0%, Cl=8.2%

Example 2: Bis(bis(2-methoxyethyl)amino)-bis(pyrrolidino)phosphonium bromide

104,12 g (0.5 mol) of phosphorus pentachloride are introduced into 400 g of chlorobenzene and cooled to -20 to 10°C. At this temperature, 133.78 g (1 mol) of bis-(2-methoxyethyl)amine are added dropwise in such a way that the internal temperature does not exceed 0°C. After the addition, the mixture is heated at 100°C for one hour.

It is then cooled again to 10°C, and 214.55 g (3.0 mol) of pyrrolidine are added dropwise in such a way that the internal temperature does not exceed 15°C.

After the addition, the mixture is heated to reflux for two hours. After cooling to 0°C, 779.94 g (3.9 mol) of 20% strength sodium hydroxide solution (equivalent to 155.99 g of NaOH) are cautiously used to make alkaline. The aqueous phase is separated off and discarded. After addition of 71.93 g (0.6 mol) of potassium bromide, excess free amine is distilled out of the organic phase. After the end of the distillation, HBr is used to acidify to pH=6-7 and, after filtration, the chlorobenzene is stripped off in a rotary evaporator.

Elemental analysis: C=46.9%, H=8.8%, N=10.6%, P=5.9%, Br=15.2%, Cl=0.14%

Example 3: (n-Butyl-ethylamino)-tris-(pyrrolidino)phosphonium bromide

42.7 g (0.6 mol) of pyrrolidine are added dropwise to 20.8 g (0.1 mol) of  $\text{PCl}_5$  in 100 ml of chlorobenzene in 1 hour so that the internal temperature does not exceed

15°C. After the addition, the mixture is stirred at 50°C for one hour and then, at a reaction temperature of 25°C, 16 g (0.22 mol) of n-butylamine are added.

After 1 hour under reflux, the mixture is again cooled to 25°C and hydrolyzed with 200 ml of ice-water, and the aqueous phase is separated off. After the excess amine has been distilled off, 19.9 g (0.5 mol) of NaOH in 20 ml of water are introduced. At 50°C, 12.0 g (0.11 mol) of ethyl bromide are added dropwise. After stirring at 70°C for 3 hours, the mixture is cooled to 25°C and diluted with 200 ml of water. The organic phase is separated off and acidified to pH =6-7 with 60% strength hydrobromic acid. After all the volatile constituents have been distilled off, 33.6 g (n-butyl-ethylamino)-tris-(pyrrolidino)phosphonium bromide are obtained as a pale brownish oil.

Example 4: Bis(methyl-tetraethoxyethylene)amino-tris(pyrrolidino)phosphonium chloride

Bis(methyl-tetraethoxyethylene)amino-tris(pyrrolidino)phosphonium chloride is prepared in analogy to Example 1 from 104.12 g (0.5 mol) of phosphorus pentachloride, 198.75 g (0.5 mol) of bis-(methyl-tetraethoxyethylene)amine ( $=\text{HN}\{(\text{CH}_2-\text{CH}_2-\text{O})_4\text{CH}_3\}_2$ ) and 214.55 g (3.0 mol) of pyrrolidine.

Elemental analysis: C=53.6%, H=9.6%, N=8.1%, P=4.3%, Cl=5.6%

Example 5: Bis(bis(methyl-tetraethoxyethylene)amino)-bis(pyrrolidino)-phosphonium chloride

Bis(bis(methyl-tetraethoxyethylene)amino)-bis(pyrrolidino)phosphonium chloride is prepared in analogy to Example 2 from 104.12 g (0.5 mol) of phosphorus pentachloride, 397.51 g (1 mol) of bis-(methyl-tetraethoxyethylene)amine ( $=\text{HN}\{(\text{CH}_2-\text{CH}_2-\text{O})_4\text{CH}_3\}_2$ ) and 214.55 g (3.0 mol) of pyrrolidine.

Elemental analysis: C=44.7%, H=8.3%, N=6.5%, P=3.7%, Cl=4.5%

Example 6: Tris(2-methoxyethyl)amino-(diethylamino)phosphonium bromide

104.12 g (0.5 mol) of phosphorus pentachloride are introduced into 400 g of chlorobenzene and cooled to  $-20$  to  $-10^{\circ}\text{C}$ . At a reaction temperature of  $<5^{\circ}\text{C}$ , 401.34 g (3 mol) of bis-(2-methoxyethyl)amine are added dropwise. After the addition, the mixture is slowly allowed to warm to  $30^{\circ}\text{C}$  and is then heated at  $100^{\circ}\text{C}$  for one hour.

At  $20^{\circ}\text{C}$ , 36g (2.1 mol) of ammonia are passed in. After hydrolysis with 850 g of 20% strength aqueous sodium hydroxide solution, the chlorobenzene and the excess bis(2-methoxyethyl)amine are distilled out of the organic phase ( $120^{\circ}\text{C}$ , 10 mbar).

The oily residue is taken up in 300 ml of chlorobenzene, and 340 g of 50% strength aqueous sodium hydroxide solution are added. At  $50^{\circ}\text{C}$ , 119 g (1.1 mol) of ethyl bromide are added dropwise, and the mixture is then stirred at  $70^{\circ}\text{C}$  for three hours to complete the reaction. Then, at  $20^{\circ}\text{C}$ , 350 ml of water are added and, after phase separation, the organic phase is neutralized with 24 g of 36% strength hydrobromic acid. Removal of all volatile constituents by distillation results in 33.6 g of tris(2-methoxyethyl)amino-(diethylamino)phosphonium bromide as a brownish oil.

Elemental analysis: C=36.1%, H=7.9%, N=7.5%, P=4.15%, Br=9.8%, Cl=0.5%.

#### Example 7: N-Methylpiperazino-tris(pyrrolidino)phosphonium chloride

41.65 g (0.2 mol) of phosphorus pentachloride are introduced into 200 g of toluene and cooled to  $-20^{\circ}\text{C}$ . Then 20.03 g (0.2 mol) of N-methylpiperazine are added dropwise in such a way that the internal temperature does not exceed  $5^{\circ}\text{C}$ . After the addition, the mixture is heated at  $100^{\circ}\text{C}$  for one hour.

At  $10^{\circ}\text{C}$ , 56.9 g (0.8 mol) of pyrrolidine are added dropwise. After the addition, the mixture is allowed to warm slowly to  $20^{\circ}\text{C}$ . After a further 30 min, it is heated to reflux for two hours.

After hydrolysis with 20% strength aqueous sodium hydroxide solution, the toluene and the excess amine are distilled out of the organic phase ( $120^{\circ}\text{C}$ , 10 mbar). 69.6 g of N-methylpiperazino-tris(pyrrolidino)phosphonium chloride are obtained as a brownish oil.

Elemental analysis: C=54.3%, H=9.6%, N=18.5%, P=8.15%, Cl=9.7%

#### Example 8: Dioctylamino-tris(pyrrolidino)phosphonium chloride

Dioctylamino-tris(pyrrolidino)phosphonium chloride is prepared in analogy to Example 1 from 41.65 g (0.2 mol) of phosphorus pentachloride, 48.3 g (0.2 mol) of dioctylamine and 99.6 g (1.4 mol) of pyrrolidine.

- 5 Elemental analysis: C=65.3%, H=11.6%, N=10.5%, P=5.9%, Cl=7.0%

Example 9: Morpholino-tris(pyrrolidino)phosphonium chloride

- 10 Morpholino-tris(pyrrolidino)phosphonium chloride is prepared in analogy to Example 1 from 104.12 g (0.5 mol) of phosphorus pentachloride, 43.6 g (0.5 mol) of morpholine and 214.6 g (3.0 mol) of pyrrolidine.

Elemental analysis: C=52.8%, H=9.0%, N=15.3%, P=8.4%, Cl=10.1%

The corresponding bromide is obtained by salts metathesis in analogy to Example 2.

- 15 Example 10: Bis(morpholino)-bis(pyrrolidino)phosphonium chloride

Bis(morpholino)-bis(pyrrolidino)phosphonium chloride is prepared in analogy to Example 2 from 104.12 g (0.5 mol) of phosphorus pentachloride, 87.12 g (1 mol) of morpholine and 214.55 g (3.0 mol) of pyrrolidine.

- 20 Elemental analysis: C=50.6%, H=8.7%, N=14.6%, P=8.0%, Cl=9.5%

The corresponding bromide is obtained by salt metathesis in analogy to Example 2.

Example 11: Bis(2-methoxyethyl)amino-tris(piperidino)phosphonium chloride

Bis(2-methoxyethyl)amino-tris(piperidino)phosphonium chloride is prepared in analogy to Example 2 from 104.12 g (0.5 mol) of phosphorus pentachloride, 66.9 g (0.5 mol) of bis-(2-methoxyethyl)amine and 255.4 g (3.0 mol) of piperidine.

Example 12: Bis(bis(2-methoxyethyl)amino)-bis(piperidino)phosphonium chloride

Bis(bis(2-methoxyethyl)amino)-bis(piperidino)phosphonium chloride is prepared in analogy to Example 1 from 104.12 g (0.5 mol) of phosphorus pentachloride, 133.2 g (1 mol) of bis-(2-methoxyethyl)amine and 212.9 g (2.5 mol) of piperidine.

Comparative Example A: Tetrakis(diethylamino)phosphonium bromide  
(Comparison substance)

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109.7 g (1.5 mol) of diethylamine are added dropwise to a 52.1 g (0.25 mol) of  $\text{PCl}_5$  in 220 ml of chlorobenzene in 1 hour so that the internal temperature does not exceed 5°C. After the addition, the mixture is stirred at 30°C for one hour and then, at T=15°C, 30 g of ammonia are passed in:

20 After 1 hour, 340 g of 20% strength sodium hydroxide solution are added, and the aqueous phase is separated off. The excess diethylamine is distilled out of the organic phase. Then 170 g of 50% strength sodium hydroxide solution and 60 g (0.55 mol) of ethyl bromide are added, and the mixture is heated at 50°C for 4 hours. After phase separation, the organic phase is acidified to pH=6-7 with 60% strength  
25 hydrobromic acid. Removal of all the volatile constituents by distillation results in 83.9 g of tetrakis(diethylamino)phosphonium bromide as a pale brownish oil.

Comparative Example B: Tris(dibutylamino)-(diethylamino)phosphonium bromide  
(Comparison substance)

30

Tris(dibutylamino)-(diethylamino)phosphonium bromide is prepared in analogy to Comparative Example A from 41.65 g (0.2 mol) of phosphorus pentachloride,

77.50 g (0.6 mol) of dibutylamine, an excess of ammonia and 47.9 g (0.44 mol) of ethyl bromide.

Elemental analysis: C=53.2%, H=10.9%, N=12.3%, P=6.75%, Br=16.3%, Cl=0.7%

Testing of the catalytic activity:

- 5 Preparation of 2,6-difluorobenzaldehyde (DFBAL) from 2-chloro-6-fluorobenzaldehyde (CFBAL) by chlorine-fluorine exchange reaction

#### Comparative Example 1 A and 1 B

- 10 At 60°C, 4.4 g (0.01 mol) of tetrakis(diethylamino)phosphonium bromide (Comparative Example 1 A) or 5.7 g (0.01 mol) of tris(dibutylamino)-(diethylamino)-phosphonium bromide (Comparative Example 1 B) and, in each case, 17.6 g (0.03 mol) of methyl-tris(methyltetraethoxy)ammonium chloride  $[(CH_3-(O-C_2H_4)_4)_3NCH_3]Cl$ , 58.3 g (1 mol) of potassium fluoride and 10 ml of
- 15 chlorobenzene are successively added to 158.6 g (1 mol) of 2-chloro-6-fluorobenzaldehyde (CFBAL). The reaction mixture is dried by azeotropic distillation of the chlorobenzene under reduced pressure. After 20 hours at 170°C, the formation of 2,6-difluorobenzaldehyde (DFBAL) and the conversion in the reaction are determined by gas chromatography.

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#### Examples

- In the following examples identified by an \* in Table 1, in place of tetrakis(diethylamino)phosphonium bromide there is used an equivalent molar
- 25 quantity of the aminophosphonium salt indicated in each case in Table 1 (0.01 mol in each case) and 0.03 mol of methyl-tris(methyltetraethoxy)ammonium chloride. The procedure is otherwise analogous to Comparative Example 1A.
- The numerical data in Table 1 correspond to GC percentage areas. The difference from 100% (remainder) which is likewise indicated in Table 1 is a measure of side
- 30 reactions and decomposition.

Table 1:



Yields of 2,6-difluorobenzaldehyde (DFBAL) from the halex reaction of 2-chloro-6-fluorobenzaldehyde (CFBAL) in GC% areas

Aminophosphonium salt	DFBAL	CFBAL	Remainder
No catalysts	16.2	72.1	11.7
$[(Et_2N)_4P]Br$	56.1	24.7	19.2
$[(Bu_2N)_3(Et_2N)P]Br$	63.0	20.1	16.9
$[(Me(OCH_2CH_2)_2N)(pyrrolidino)_3P]Br^*$	68.9	15.0	16.1
$[(Me(OCH_2CH_2)_2N)(pyrrolidino)_3P]Cl^*$	67.7	17.8	14.5
$[(Me(OCH_2CH_2)_2N)_2(pyrrlidino)_2P]Br^*$	70.2	12.3	17.5
$[{(Et)(Bu)N}(pyrrolidino)_3P]Br^*$	64.4	22.6	13.0
$[{(Me(O-C_2H_4)_4)_2N}(pyrrolidino)_3P]Br^*$	71.5	18.4	10.1
$[{(Me(O-C_2H_4)_4)_2N)_2(pyrrlidino)_2P]Br^*$	70.8	17.2	12.0
$[(N-Me(piperazino)(pyrrolidino)_3P]Cl^*$	68.2	18.2	13.6
$[(Morpholino)(pyrrolidino)_3P]Br^*$	68.5	18.1	13.4
$[(Morpholino)(pyrrolidino)_3P]Cl^*$	68.2	17.1	14.7
$[(Morpholino)_2(pyrrlidino)_2P]Br^*$	66.3	19.7	14.0
$[(Morpholino)_2(pyrrlidino)_2P]Cl^*$	65.8	20.1	14.1
$[(Me(OCH_2CH_2)_2N)(piperidino)_3P]Cl^*$	71.2	16.8	12.0
$[(Me(OCH_2CH_2)_2N)_2(piperidino)_2P]Cl^*$	70.4	18.2	11.4

\* Examples

Testing of the catalytic activity:

- 5 Preparation of 2,6-difluorobenzaldehyde (DFBAL) and 2-chloro-6-fluorobenzaldehyde (CFBAL) from 2,6-dichlorobenzaldehyde (DCBAL) by chlorine-fluorine exchange reaction.

Comparative Example 2 A and 2 B

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At 60°C, 8.8 g (0.02 mol) of tetrakis(diethylamino)phosphonium bromide (Comparative Example 2 A) or 11.35 g (0.02 mol) of tris(dibutylamino)(diethylamino)phosphonium bromide (Comparison Example 2 B) and, in each case, 35.2 g (0.06 mol) of methyl-tris(methyltetraethoxy)ammonium chloride, 116.2 g (2 mol) of potassium fluoride and 10 ml of chlorobenzene are

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successfully added to 175.0 g (1 mol) of 2,6-dichlorobenzaldehyde (DCBAL). The reaction mixture is dried by azeotropic distillation of the chlorobenzene under reduced pressure. After 20 hours at 165°C, the formation of 2-chloro-6-fluorobenzaldehyde (CFBAL) and 2,6-difluorobenzaldehyde (DFBAL) and the conversion in the reaction are determined by gas chromatography.

### Examples

In the following examples identified by an \* in Table 2, in place of tetrakis-(diethylamino)phosphonium bromide there is used an equivalent molar quantity of the aminophosphonium salt indicated in each case (0.02 mol in each case) and 0.06 mol of methyl-tris(methyltetraethoxy)ammonium chloride. The procedure is otherwise analogous to Comparative Example 2A.

The numerical data in Table 2 correspond to GC percentage areas. The difference from 100% (remainder) which is likewise indicated in Table 2 is a measure of side reactions and decomposition.

Table 2:

Yields of 2,6-difluorobenzaldehyde (DFBAL) and 2-chloro-6-fluorobenzaldehyde (CFBAL) from the halex reaction of 2,6-dichlorobenzaldehyde (DCBAL) in GC% areas

Aminophosphonium salt	DFBAL	CFBAL	DCBAL	Remainder
no catalyst	1.2	11.4	71.5	15.9
$[(Et_2N)_4P]Br$	40.2	26.9	11.2	21.7
$[(Bu_2N)_3(Et_2N)P]Br$	41.1	27.5	10.4	21.0
$[(Me(OCH_2CH_2)_2N)(pyrrolidino)_3P]Br$ *	51.1	36.1	1.8	11.0
$[(Me(OCH_2CH_2)_2N)(pyrrolidino)_3P]Cl$ *	50.7	37.8	2.1	9.4
$[(Me(OCH_2CH_2)_2N)_2(pyrrlidino)_2P]Br$ *	50.6	37.3	1.4	10.7
$[(Et)(Bu)N](pyrrolidino)_3P]Br$ *	43.6	31.2	8.6	16.6
$[(Octyl_2N)(pyrrolidino)_3P]Br$ *	41.6	33.5	8.1	16.8

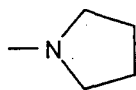
Aminophosphonium salt	DFBAL	CFBAL	DCBAL	Remainder
$[\{(Me(O-C_2H_4)_4)_2N\}(pyrrolidino)_3P]Br^*$	53.8	31.4	3.9	10.9
$[\{(Me(O-C_2H_4)_4)_2N\}_2(pyrrrolidino)_2P]Br^*$	50.4	36.8	2.1	10.7
$[(N-Me(piperazino))(pyrrolidino)_3P]Cl^*$	46.9	38.2	4.4	10.5
$[(Morpholino)(pyrrolidino)_3P]Br^*$	46.9	32.3	5.1	15.7
$[(Morpholino)(pyrrolidino)_3P]Cl^*$	47.2	34.8	5.4	12.6
$[(Morpholino)_2(pyrrrolidino)_2P]Br^*$	47.8	35.6	5.2	11.4
$[(Morpholino)_2(pyrrrolidino)_2P]Cl^*$	49.6	31.9	4.8	13.7
$[(Me(OCH_2CH_2)_2N)(piperidino)_3P]Cl^*$	54.2	34.4	1.7	9.7
$[(Me(OCH_2CH_2)_2N)_2(piperidino)_2P]Cl^*$	53.1	35.5	1.5	9.9

\* Examples

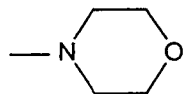
In Tables 1 and 2, Me stands for methyl, Et for ethyl and Bu for butyl,  $Me(O-C_2H_4)_4$  for methyl-tetraethoxyethylene

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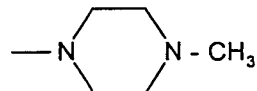
Pyrrolidino for



Morpholino for



10 N-Me(piperazino) for



and piperidino for

